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TRANSLATION

CORROSION STABILITY OF LOW-CARBON AND LOW-ALLOY STEELS IN SEA WATER

By

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FOREIGN TECHNOLOGY DIVISION

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BY: G. G. Koshelev and I. L. Rozenfel'd

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CORROSION STABILITY OF LOW-CARBON AND LOW-ALLOY STEELS IN SEA WATER

G. G. Koshelev and I. L. Rozenfel'd

Carbon and low-alloy steels are basic materials for building of ships and hydrotechnical constructions. Corrosion stability of carbon and low-alloy steels in sea water has been studied by many authors: however, there is no single opinion on the question of the appraisal of corrosion stability of steels in sea water. G. V. Akimov [1] considers that the structure of metal plays a subordinate role and does not have an essential influence on corrosion stability of steels in sea water.

A. A. Babakov, V. F. Negreyev, et. al. [2], on the basis of tests of corrosion stability of different steels conducted in the Caspian sea, consider that the speed of corrosion of low-alloy steels SKhLF and SKhLF2 is 10--12 0/0 less than that of carbon steels.

Steel ML2 with addition of 1 0/0 aluminum or with addition of 3 0/0 chromium has a speed of corrosion 25--30 0/0 lower than that of carbon steels.

S. G. Vedenkin [3], on the basis of laboratory investigations, considers that low-alloy steels possess higher corrosion stability in sea water than do carbon.

Generalizing results of tests of steels at marine corrosion stations in a number of countries, F. La-Ke [4] arrived at the conclusion that alloying additions in quantities of no more than 5 0/0 have practically no influence on the speed of corrosion of steels in sea water. Yu. R. Evans [5], conversely, affirms that introduction of small additions of copper, aluminum and manganese

significantly increases corrosion stability of steels in sea water.

In the work of Hudson and Stanulrs [6] are given results of five-year tests of more than 60 types of different steels in atmosphere and in the sea. Results of tests of steels in the sea showed that additions of Ni and Cr of up to 3 0/0 increase corrosion stability only in initial period of test (up to two years): after five years the speed of corrosion of low-alloy steels is of the same order as that of carbon steel. Increased corrosion stability in the sea was shown only by steels containing aluminum and chromium. The different opinions about the corrosion stability of carbon and low-alloy steels in sea water do not allow a simple answer to the question of what kind of steel it is expedient to apply in naval shipbuilding and in the building of naval hydrotechnical constructions.

Therefore the Institute of Physical Chemistry of the Academy of Sciences of USSR, together with the factory imeni, Il'yich conducted work in the investigation of corrosion stability of the steels Steel 3, SKhL1, MS1, and MK in the sea. Tests were conducted for the purpose of ascertaining the influence of alloying components, thermal processing, and the presence of scale on the corrosion stability of the enumerated steels. All the types of steels were smelted by the factory imeni. Il'yich in open-hearth furnaces by factory procedure. The chemical composition of the steels is given in Table 1. Billets were rolled to sheet 3mm thick. Some of the sheets were additionally subjected to normalization at a temperature of 900° and subsequent tempering at a temperature of 650°. Thus, all types of steels were prepared for tests in three forms: 1) as-delivered; 2) heat treated with scale; 3) heat treated without scale.

Table 1

Chemical composition of studied steels

1 Марка стали	2 Содержание элементов, %							
	C	Mn	Si	P	S	Cr	Ni	Cu
3 Ст.3	0,15	0,42	7 Следы	0,024	0,037	—	—	—
4 СХЛ1	0,16	0,53	0,50	0,034	0,030	0,86	0,36	0,34
5 МС1	0,12	0,99	0,99	0,026	0,026	0,25	1,06	0,33
6 МК	0,12	1,55	0,88	0,031	0,025	0,14	Следы	0,40

1) Type of steel; 2) Contents of elements, 0/0; 3) Steel 3; 4) SKhL1; 5) MS1; 6) MK; 7) Traces.

Samples with dimensions of 260 X 180 X 3 mm were fixed in steel frames (Fig. 1). For the purpose of assuring insulation the samples were secured by porcelain insulators. Frame with samples was placed on a floating stand (Fig. 2). With this the upper row of samples was disposed at a depth of 300 mm from the level of the sea, and the lower at a depth of 850 mm.

Test of samples was carried out at the corrosion station IFKh in Dal'niye Zelentsy Bay on the Barents Sea.

The composition of the sea water at the test site corresponds to the composition of ocean water.

Speed of Corrosion of Steels in the Barents Sea

Data on the corrosion of steels after six years of full submersion in the sea are given in Table 2. From table it follows that the total corrosion effect after six years constitutes 2.5--3 kg/m^2, or 420--600 g/m^2 per year.

For convenience of comparison of corrosion stability of the tested steels, the weight losses of Steel 3, at all forms of processing, are taken as 100 0/0. The given data show that the corrosion stability of low-alloy steels in the rolled state is 20--28 0/0 greater than that of Steel 3.

Thermal processing of low-alloy steels does not have an essential influence on their corrosion stability in sea water. Loss of weight of heat-treated steels is less than that of the same steels in the rolled state, but this, apparently, is stipulated by the partial destruction of scale during of heat treating.

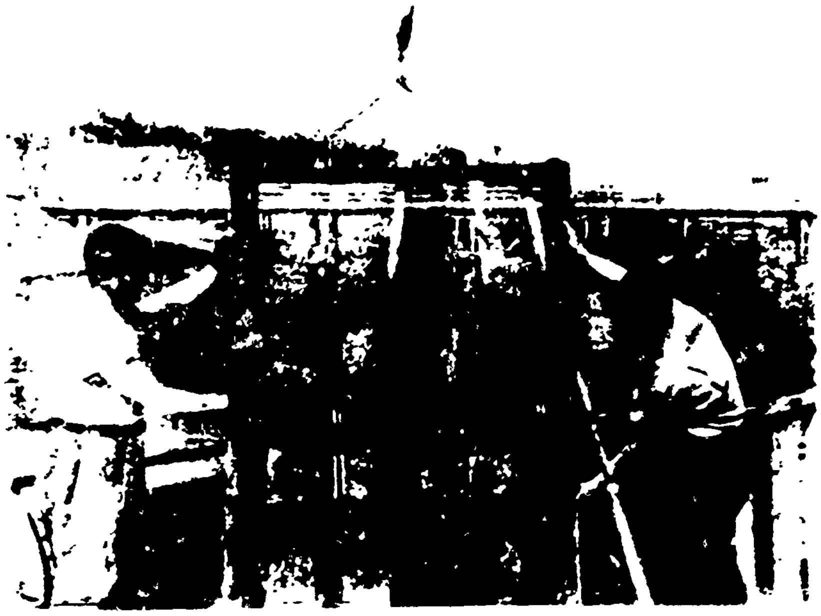

Fig. 1. Frame with samples, lifted above the sea stand.

Fig. 2. Floating sea stand.

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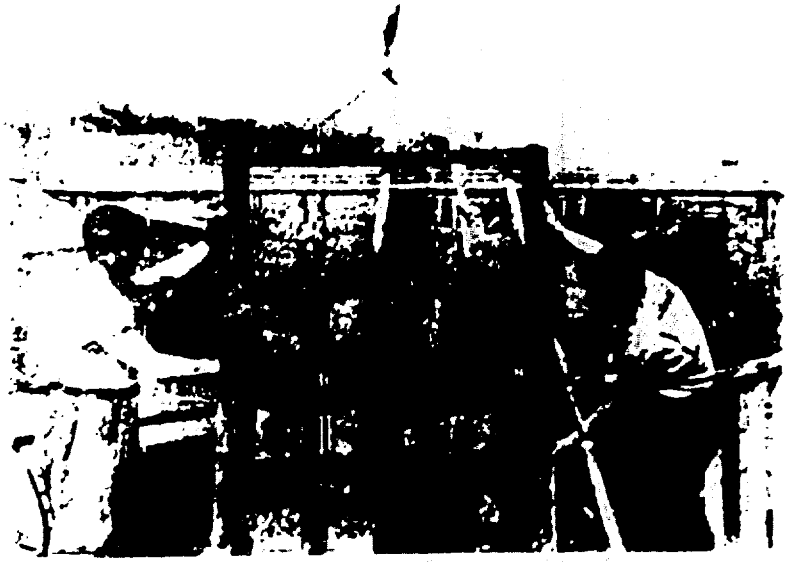

Fig. 1. Frame with samples, lifted above the sea stand.

Fig. 2. Floating sea stand.

As a result of this scale was removed from heat treated steels in the first years of the test, but on steels in the rolled state it was left longer. Prolonged preservation of scale on surface favored the work of the scale iron pair. This probable, stipulated the somewhat higher speed of corrosion of steels in the rolled state.

Steel MS1 corrodes at a somewhat lower speed than other steels with a shot-peened surface -- its loss in weight was less (420 g/m^2 per year) -- and steel SKhL1 displays the biggest losses in weight (520 g/m^2). Steel 3 and MK occupy a middle position. Steel 3, MS1, and MK after shot-peening have smaller losses of weight than steel SKhL1. In general, the weight losses of carbon and low-alloy steels from which scale has been removed are approximately identical.

Table 2

Average speed of corrosion of steels of different types in the Barents Sea after six years

1 Вид обработки стали	2 Марка стали	3 Скорость коррозии. Потеря веса, г/м²		6 Соотношение скорости коррозии стали разных марок (Ст.3 принята за 100 %)
		4 за 6 лет	5 средняя за год	
7 Прокат с окалиной	Ст.3 10	3840	640	100
	СХЛ1 11	3080	513	80
	МС1 12	3140	523	81
	МК 13	2950	491	72
8 Термически обработанные с окалиной	Ст.3 10	2910	485	100
	СХЛ1 11	3010	501	103
	МС1 12	2820	470	97
	МК 13	2810	468	96
9 Термически обработанные дробеструенные	Ст.3 10	2620	470	100
	СХЛ1 11	3160	512	109
	МС1 12	2520	420	89
	МК 13	2690	448	95

1) Type of processing of steels; 2) Type of steel; 3) Speed of corrosion -- Loss of weight, g/m^2; 4) After 6 years; 5) average per year; 6) Relationship of speed of corrosion of steels of various types (Steel 3 taken as 100 0/0); 7) Rolling with scale; 8) Heat treated with scale; 9) Heat treated, shot-peened; 10) Steel 3; 11) SKhL1; 12) MS1; 13) MK.

Loss of weight of steel SKhL1 with scale and without scale was almost identical.

In Fig. 3, 4, and 5 are given curves of the time dependence of corrosion of steels. Speed of corrosion of steels with time decreases. This apparently is explained by the fact that in the first years of tests occurs destruction of scale occurs, as a result of which the weight losses of steels are higher in the initial period of corrosion. In subsequent years the speed of corrosion of steels is less, owing to the absence of weight losses caused by destruction of scale and to a certain braking of speed of corrosion due to overgrowth of the metal surface by products of corrosion. Steel 3 in the as-delivered state during the period of six years was corroded at the highest speed, and steel MK--at the lowest.

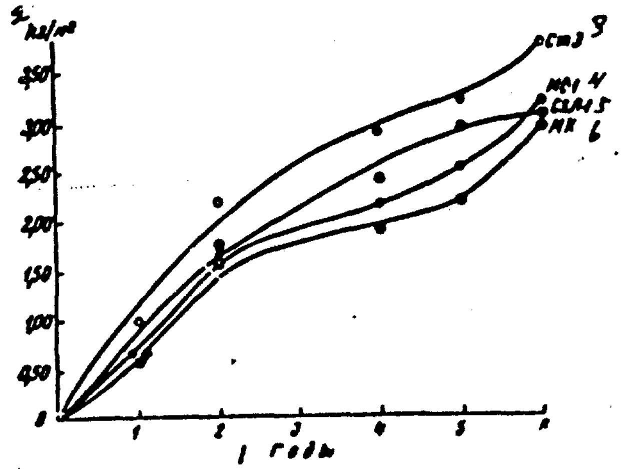

Fig. 3. Loss of weight of samples of steel of different types in as-delivered state, placed in sea in for six years.
1--Years; 2--Kg/mm^2; 3--Steel 3; 4--MS1: 5--SKhL-4: 6--MK.

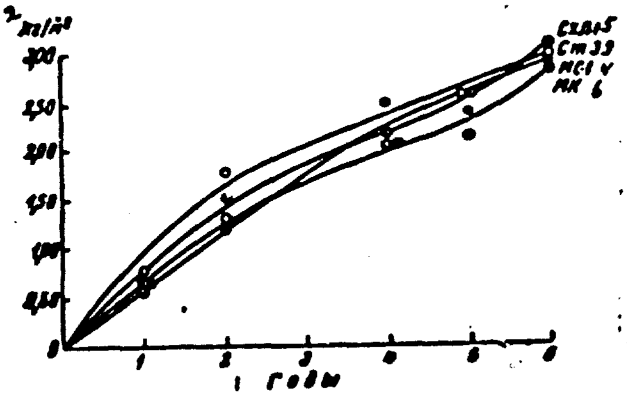

Fig. 4. Loss of weight of heat treated samples of steel placed in sea in for six years.
1--Years; 2-6--same as Fig. 3.

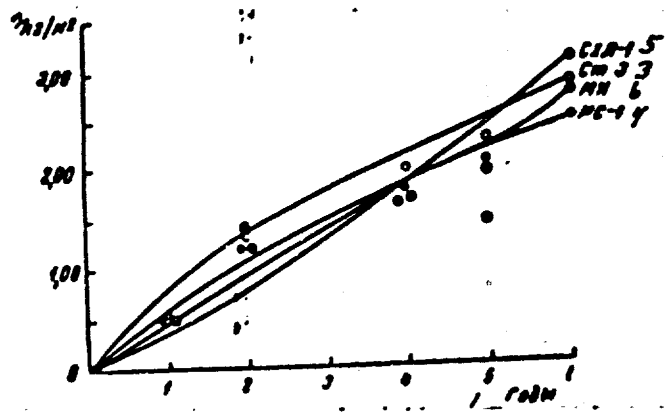

Fig. 5. Loss of weight of samples of steel without scale, placed in sea for six years.
1--Years; 2-6--Same as Fig. 3.

Table 3

Steel sample surface area on which scale was retained after six-year tests in the Barents Sea

1 Марка стали	2 Вид обработки сталей	3 Площадь, на которой сохранялась окалина	
		см²	4 % от общей площади поверхности образцов
Ст.3 5	9 Прокат Термически обработанные 10	38 23	4 2
СХЛ1 6	9 Прокат Термически обработанные 10	22 10	2 1
МС1 7	9 Прокат Термически обработанные 10	405 127	42 14
МК 8	9 Прокат Термически обработанные 10	242 69	26 7

1) Type of steel; 2) Form of processing of steels; 3) Area on which scale was retained; 4) 0/0 of general surface area of samples; 5) Steel 3; 6) SKhL1; 7) MS1; 8) MK; 9) Rolling; 10) Heat treated.

Steel in the heat treated condition corrodes at a somewhat lesser speed (Fig. 4) than steel in the as-delivered state. Speed of corrosion of steels with shot-peened surfaces is less than that of steels with scale. This indicates the significant role of scale in strengthening corrosion. Carbon and low-alloy steels free from scale corrode in sea water at approximately identical speeds.

From the data of Table 2 it follows that weight losses of steels in the as-delivered state are, on the whole, 13% larger than those of heat treated steels with scale. To ascertain the factors affecting the corrosion resistance of as-delivered and heat treated steels, the surface area on which scale remained after tests was calculated. Calculation data are presented in Table 3. From consideration of the table it follows that on as-delivered samples of steels the surface area on which scale was retained is 2--3 times greater than that on heat treated samples.

Apparently, heating of steel sheets to high temperatures leads to additional growth of scale and the appearance in it of micro-cracks due to the different coefficients of expansion of scale and base metal--steel; this promotes faster destruction of scale. Weight losses of steels in as-delivered state were somewhat larger than those of heat treated steels. This, apparently, was stimulated by the more prolonged work of the scale metal pairs on steels in as-delivered state. On samples of steels M31 and MK, scale was retained significantly longer than on Steel 3. This, probably, was stimulated by the presence of alloying components in the steels.

It was noted that steels with scale have a more clearly expressed inclination to corrosion with formation of deep pits. To clarify this phenomenon, potentials were measured of sections with and without scale on one and the same sample of every tested type of steel under incomplete polarization of the system. The latter was attained by applying, by special processes, electrolyte only on section whose potential was measured. Measurement of potentials was conducted in sea water. Measurement data are presented in Table 4. From an examination of the table it is clear that sections without scale have more negative potentials than sections, covered with scale. The difference of potentials of these sections for steels SKhL1 and MS1 constitutes near 27 millivolt, but for Steel 3 and MK -- only 14 millivolt.

Thus, on surface of steels there are comparatively strong pairs where the cathode is the sections, covered with scale, and the anode -- sections of steel without scale. Since on steels SKhL1 and M31 the difference of potentials of these sections is greater than on Steel 3 and MK, the inclination of these steels to pitting with formation of deep seats is significantly larger.

Table 4

Surface potentials of samples on sections with and without scale in sea water (in relation to hydrogen electrode)

1 Марка стали	2 Потенциал участков без окалины, мв	3 Потенциал участков с окалиной, мв	4 Разность потенциалов, мв
5 Ст.3	—322	—308	14
6 СХЛ1	—323	—297	26
7 МС1	—327	—299	28
8 МК	—360	—346	14

1) Type of steel; 2) Potential of sections without scale,millivolt; 3) Potential of sections with scale,millivolt; 4) Difference of potentials, millivolt; 5) Steel 3; 6) SKhL1; 7) MS1; 8) MK

Depth of Corrosion Pits On Steels After Tests in the Barents Sea

Weight losses of steels due to pitting cannot completely characterize their behavior in sea water, especially since the difference in weight losses of low-alloy and carbon steels is insignificant. In this case data on the depth of corrosion pits are one of main indices characterizing the corrosion behavior of steels in the sea.

Table 5

(See Table 5 On Following Page)

Table 5

Depth of corrosion pits on steels tested in the Barents Sea (original thickness of samples, 3mm)

Способ обработки сталей 1	Марка сталей 2	3 Глубина язв, мм						9 Средняя потеря толщины за 6 лет коррозии, мм/год
		4 через 2, 3 года		7 через 4 года		8 через 5 лет		
		5 средняя	6 наибольшая	5 средняя	6 наибольшая	5 средняя	6 наибольшая	
10 Прокатанные	Ст.3 13	0,56	0,79	0,27	0,63	0,23	0,41	0,082
	СХЛ1 14	0,60	0.71	0,45	0,78	0,44	0,9	0,066
	МС1 15	0,44	0,90	0,38	0,91	0,37	1,00	0,069
	МК 16	0,41	0,61	0.37	0,65	0,24	0,65	0,069
11 Термообработанные	Ст.3 13	0,47	0,70	0,30	0,68	0,19	0,43	0,062
	СХЛ1 14	0,40	0,45	0,27	0,58	0,28	0,70	0,064
	МС1 15	0,47	0,64	0,28	0,55	0,30	0,61	0,060
	МК 16	0,34	0,61	0,27	0,53	0,23	0,57	0,060
12 Дробеструенные	Ст.3 13	0,32	0,54	0,20	0,57	0,19	0,39	0,060
	СХЛ1 14	0,42	0,59	0,21	0,65	0,22	0,71	0,065
	МС1 15	0,34	0,47	0,25	0,54	0,23	0,43	0,054
	МК 16	0,34	0,51	0,20	0,50	0,18	0,49	0,057

1) Method of processing of steels; 2) Type of steels; 3) Depth of pits, mm, 4) after 2, 3 years; 5) average; 6) greatest; 7) after 4 years; 8) after 5 years; 9) average loss of thickness after 6 years of corrosion, mm/year; 10) Rolled; 11) Heat treated; 12) shot-peened; 13) Steel 3; 14) SKhL1; 15) MS1; 16) MK.

Measurements of the depth of attack were made by us on both sides of samples at twenty points on a diagonal. Depth of pits was measured at ten points in the deepest places. In Table 5 are given data on the depth of pits in steels tested in the Barents Sea. From examination of the table it is clear that the greatest depth of pits was observed at the end of two years' immersion of the steels in the sea; in subsequent years the average depth of pits was somewhat decreased. This is stimulated by the fact that in the first years of the test corrosion proceeded on small anodic sections in places where the scale was

damaged. With an increase in test time the surface of the anodic sections increased due to destruction of scale, and as a result of this corrosion proceeded flowed more evenly over the whole surface of the sample.

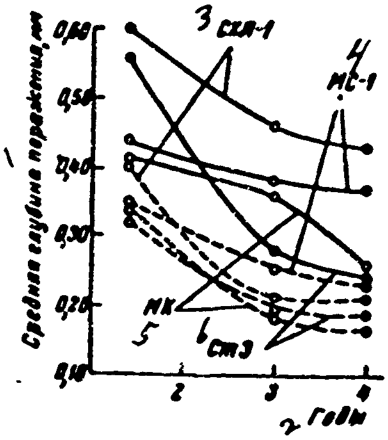

Fig. 6. Change with time of depth of corrosion pits on steels in time. Solid curves--as-delivered; dotted curves--without scale
1--Average depth of attach, mm; 2--Years; 3--SKhL-1; 4--MS-1; 5--MK; 6--Steel 3.

In Fig. 6 are presented curves of change in time of depth of pits on steels with and without scale. From the drawing is clear that depth of corrosion pits on steels of all types decreased with time. From the drawing also it is clear that MK steel corrodes the most evenly. Deeper corrosion pits were detected on steels SKhL1 and MS1 with scale. In separate places the depth of pits on these steels attained 1.5 mm; on two samples the attack went through.

In the last column of the tables are presented data on the decrease in thickness of steels, calculated from their weight losses after six years. The thickness of the steels was decreased by 0.06--0.0[illegible] mm/year; the difference in the decrease of thickness of different steels was insignificant.

Changes of Mechanical Properties of Steels Owing to Corrosion

Another very important index of corrosion of steels is the change in their mechanical properties in the process of corrosion. Ultimate strength after corrosion is also characterized by the irregularity of corrosion, since failure occurs in the weakest section of the sample. In Table 6 are given data on the

loss of mechanical properties of steels during full submersion in the sea, after five-year tests. In the calculation of loss of mechanical properties, loads were referred to the initial section of samples.

From examination of the table it follows that loss of yield point σ_S and ultimate strength σ_B for steels with different processing constitutes 20--35 0/0 after five years.

Loss of plastic properties δ by steels during the test period was somewhat less, however, constituting 10--30 0/0. Steels with shot-peened surfaces showed a somewhat smaller loss of mechanical properties, especially plastic.

Steels 3KhL1 and M31 displayed the greatest loss of mechanical properties with all forms of processing, and steel MK--the least. Plastic properties of steels 3KhL1 and M31 were lowered twice as much as those of steel MK.

In Fig. 7 are presented curves of change of yield point σ_S (1) and ultimate strength σ_B (IV) of as-delivered due to corrosion. The curves have a large inclination angle in the first two year of tests,which attests to the signifi ant decrease of yield in this period. This is explained by the fact that corrosion in the first years of test of steels with scale proceeds mainly at the expense of formation of local pits in places where scale is broken or completely removed.

After two years the curves of yield point and ultimate strength have a very insignificant slope, which is explained by great uniformity of corrosion.

On the same drawing are shown curves of change of yield point (II) and ultimate strength (V) of heat treated steels in the course of the tests. From the drawing it is clear that steel 3KhL1 with variant of processing showed the most significant losses of yield point.

The mechanical properties of low-alloy steels with shot-peened surfaces are lower with time to an approximately equal degree (curves III and VI, Fig. 7).

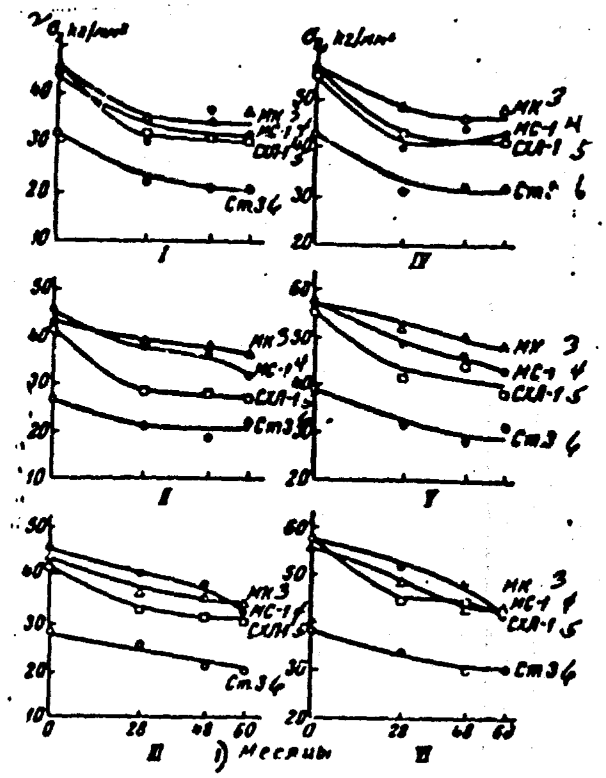

Fig. 7. Change of yield point σ_s and tensile strength σ_p during corrosion of steels in sea water.
I--IV--with scale, as-delivered; II-V--with scale, heat treated; III--VI--without scale.
1--Months; 2--σ_s, Kg/mm^2; 3--MK; 4--MS-1; 5--SKhL-1; 6--Steel 3 (3-6 are the same in all diagrams).

That fact that MK steel with all forms of processing has approximately identical losses of mechanical properties indicates that this steel corrodes more evenly than the other steels. This confirms our conclusion, made on the basis of the external appearance of samples of MK steel.

As was already indicated, the greatest loss of mechanical properties with all variants of processing was shown by steel SKhL1. Large losses of mechanical properties by steel of this type are stipulated mainly by the fact that its corrosion proceeds less evenly than that of the other steels tested, with the formation of local deep pits.

Steel MS1 in magnitude of losses of mechanical properties occupies second place.

Mechanical properties of Steel 3 prior to test were approximately on 28--36 0/0 lower than those of the low-alloy steels SKhL1, MS1 and MK. Loss of mechanical strength by Steel 3 without scale in five-year tests appeared to be somewhat less than losses of steels SKhL1 and MS1; however, the mechanical strength of Steel 3 after the tests was approximately 25 0/0 less than the remaining strength of steels SKhL1 and MS1.

Table 6

Loss of mechanical properties of low-alloy steels after 5-year test in Barents Sea.

1 Обработка сталей	2 Марка стали	3 Предел текучести (σ_s), кГ/мм²		6 Потеря предела текучести, %	7 Сопротивление разрыву ($\sigma_в$), кГ/мм²		8 Потеря прочности, %	9 Удлинение (δ), %		6 Потеря пластичности, %
		4 до испытания	5 после испытания		4 до испытания	5 после испытания		4 до испытания	5 после испытания	
10 Прокат с окалиной	Ст.3	32	20	38	42	30	29	24	18	25
	СХЛ1	44	31	30	57	40	30	18	13	28
	МС1	45	32	29	56	41	27	19	15	21
	МК	45	36	20	57	45	21	17	15	12
11 Термически обработанные с окалиной	Ст.3	28	21	26	39	30	23	25	20	20
	СХЛ1	41	26	37	56	37	34	19	13	32
	МС1	44	29	34	57	40	30	21	15	29
	МК	43	32	26	57	46	19	19	17	10
12 Термически обработанные дробеструенные	Ст.3	28	19	32	39	30	24	25	22	12
	СХЛ1	41	30	27	56	42	28	19	15	21
	МС1	44	30	32	57	42	26	21	17	21
	МК	43	32	26	57	43	23	19	17	10

1) Processing of steels; 2) Type of steel; 3) Yield point (σ_s), kg/mm²; 4) Prior to test; 5) after test; 6) loss of yield point, 0/0; 7) Tensile strength (σ_B), kG/mm²; 8) loss of strength, 0/0; 9) Elongation (δ), 0/0; 10) Rolled with scale; 11) Heat treated with scale; 12) Heat treated, shot-peened; 13) Steel 3; 14) SKhL1; 15) MS1; 16) MK.

Analysis of losses of mechanical properties of steels due to corrosion showed that a significant lowering of mechanical properties of steels with scale occurs in the first two years of test in the sea; in subsequent years, lowering of mechanical properties occurs more slowly. Lowering of mechanical properties of steels without scale occurs evenly over the entire test period. Ultimate strength of Steel 3 and MK with scale was lowered by 23 0/0, and of steels SKhL1 and MS1 by 32 0/0. Lowering of the yield point of Steel 3 and MK without scale constitutes 23 0/0, and for steels SKhL1 and MS1 -- 27 0/0.

Thus the data on the change of mechanical strength after corrosion confirmed the conclusions that steels SKhL1 and MS1 corrode less uniformly than Steel 3 and MK.

Steel MK, both with and without scale, showed the least losses of mechanical properties. After tests the mechanical strength of this steel was 30--35 0/0 greater than that of Steel 3.

Thus from consideration of the data on loss of weight and mechanical strength in the course of six-year tests in the sea it can be concluded that additions in steel of the alloying components Cu, Ni, Cr, and Mn in a total not exceeding 2.5 0/0 do not increase the corrosion resistance of steels in sea water. Weight losses of these low-alloy steels during tests in natural atmosphere were 2--3 times less than those of carbon steels [7]. So great a difference in the corrosion behavior of steels in the sea and the atmosphere, apparently, is explained by several causes.

It is known that the process of corrosion of steels in sea water proceeds with oxygen depolarization. Consequently, the speed of corrosion is basically determined by the diffusion rate of oxygen into cathode sections of the metal.

Even with a small quantity of cathode sections the entire content of oxygen in water can be used; the access of the oxygen is limited by diffusion rate. A further increase in the number of cathode sections does not bring with it an increase in the quantity of oxygen arriving at the cathode in a unit of time.

As a result, the corrosion of steels proceed at a single speed, regardless of how much of the surface of the metal is constituted of cathode.

Another cause, thanks to which carbon and low-alloy steels corrode sea water at identical speeds, consists in the fact that if the corrosion process proceed so that cathodic and anodic polarization play identical roles, then change of area of cathode wi not bring with it an increase in corrosion current. This is illustrated graphically by the Evans diagram (Fig. 8).

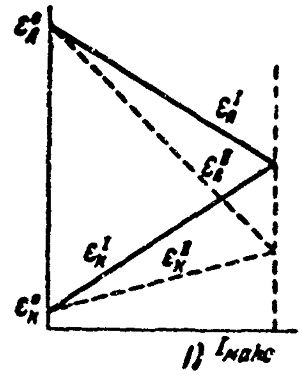

Fig. 8. Evans diagram, showing that maximum corrosion current does not change, if with an increase in F_K there is a simultaneous decrease in F_A, with a corresponding change of polarization (G. V. Akimov [1]).
1) Maximum.

Conclusions

Results of six-year tests of steels in the Barents Sea showed the following.

1. The low-alloy steels SKhL1, MS1, and MK and the carbon steel Steel 3 during full submersion in the sea corrode at approximately identical speeds. Their weight losses after six years constituted 2.5--3 kg/m^2. The average speed of corrosion of the steels during full submersion in the sea constitutes 0.5 kg/m^2 per year. Permeability or loss of thickness of metal constitutes 0.06 mm/year (calculation on even corrosion).

2. Steels SKhL1 and MS1 have a somewhat larger inclination to pitting than Steel 3 and MK, which corrode more evenly; Steel 3 corrodes especially evenly. Depth of corrosion pits of steels SKhL1 and MS1 after five years attains 1 mm, but depth of corrosion pits on Steels 3 and MK constitutes only 0.4--0.6 mm.

3. Speed of corrosion of steels without scale is 5-10 0/0 less than that of steels with scale. Steels without scale corrode more evenly than those with scale.

4. Heat treatment of Steel 3 increases its corrosion resistance by 20 0/0. Heat treatment of steels MS1, SKhL1, and MK does not have an essential influence on their corrosion resistance.

5. Loss of mechanical strength of steels, i.e., loss of ultimate strength and yield point after five-year tests in the sea, constitutes from 20 to 37 0/0.

Loss of plastic properties of steels after the same period constitute from 10 to 30 0/0.

6. Steels SKhL1 and MS1 showed somewhat larger losses of mechanical properties than Steel 3 and MK.

7. MK Steel with all variants of processing has approximately identical loss of mechanical properties, which attests to the evenness of the corrosion of this steel stood.

Conclusion

The average speed of corrosion in the sea of the tested steels is almost identical. Consequently, alloying by small additions of Cr, Ni, Cu, and Mn does not increase corrosion resistance of the steel in the sea to a noticeable degree.

Low-alloy steels differ from carbon by the fact that they corrode less evenly in the sea. This promotes a somewhat large loss of their mechanical properties (by 5--3 0/0, as compared with Steel 3).

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